MBS-AM-12-185

ACQUISITION RESEARCH SPONSORED REPORT SERIES

Business Models for Cost Sharing & Capability Sustainment

18 August 2012

by

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Prepared for: Naval Postgraduate School, Monterey, California 93943

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE
18 AUG 2012

2. REPORT TYPE

3. DATES COVERED
00-00-2012 to 00-00-2012

4. TITLE AND SUBTITLE
Business Models for Cost Sharing & Capability Sustainment

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
The University of Manchester,Manchester Business School,Sackville Street Building,Manchester, United Kingdom M13 9PL,

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**59**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

The research presented in this report was supported by the Acquisition Research Program of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

Abstract

Cost sharing in defense acquisition, with contractors sharing part of the burden of research, development, test and evaluation (RDT&E) costs, has been suggested as a way of reducing the liability of government to program cost overruns. While capping the costs of RDT&E and production is an excellent objective, incentivizing contractors may benefit from business models that span the entire life cycle of a program. The potential to share the risk of cost overruns outside RDT&E and production, and into the operations and support (O&S) area provides a powerful incentive to get contractors to “buy in” to cost sharing, and to control total program life-cycle costs.

The research presented in this report aims to identify potential new business models that would allow contractors to benefit from cost sharing across all stages of program life cycles, with a view to limiting costs during RDT&E, production, and O&S. Experience from the United Kingdom on availability contracting shows possible business models that could form the basis of an approach to cost sharing in O&S, as well as the weaknesses of some approaches tried.

Keywords: Business models, costing, capability, sustainment, defense acquisition, products, complexity, operations, support, maintenance, combat aircraft

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Acknowledgments

The author would like to thank staff at BAE Systems who read draft material that features in this paper, several anonymous interviewees within the company, and colleagues in Manchester Business School and the University of Manchester Aerospace Research Institute who have been helpful with discussions during the research.

Graham Roe, former military requirements director at BAE Systems, was also very supportive through discussions, and kindly gave a very useful seminar on the future of the defense aerospace business as part of the work supporting this paper.

Ted Hermann at Boeing St. Louis provided useful information on the F/A-18E/F Super Hornet.

Larrie Ferreiro at the DAU in Washington was instrumental in developing the research and highlighting its relevance in a U.S. context.

Fellow researchers funded by the Acquisition Research Program also provided many stimulating thoughts, notably at the Annual Acquisition Research Symposium in Monterey, CA.

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About the Author

During the period of research reported here, Mike Pryce was a research fellow at Manchester Business School in the United Kingdom. The research presented in this report follows on from his prior work for the Acquisition Research Program, *Costing Complex Products, Operations and Support* (MBS-CE-11-196; Pryce, 2011), which looked at innovative methods of costing future defense equipment.

Pryce is currently working in the BP International Centre for Advanced Materials at Manchester. He was previously part of the 10-university NECTISE (Network Enabled Capability Through Innovative Systems Engineering) research team, exploring organizational aspects of Through-Life Systems Management.

He has taught project management on MSc and MBA programs and organized the *Understanding Projects* seminar series at Manchester.

Pryce completed his PhD at the University of Sussex in 2008. His thesis, entitled *Descartes and Locke at the Drawing Board*, explored the technical, managerial, and political issues involved in the acquisition of complex engineering systems, in particular, supersonic STOVL (Short Take-Off and Vertical Landing) combat aircraft.

Pryce has previously worked in the private sector as a process engineer and business analyst and in web applications development. He holds an MSc in the history of technology from Imperial College, London.

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Introduction

The objective of the research reported here is to enable the development of new business models that allow contractors to benefit from cost sharing across all stages of program life cycles, with a view to limiting costs during research, development, test and evaluation (RDT&E), production, and operations and support (O&S). The sums involved can be very substantial—for example, in the latest estimates for the Joint Strike Fighter around 40% of the program costs (around $1 trillion to $1.45 trillion) are accounted for by RDT&E and production, with the remaining 60% accounted for by O&S.

However, the opportunities for controlling costs may vary between the stages of a program. Prior research (Pryce, 2011) indicates that RDT&E and production costs may be largely “locked in” once the degree of technical complexity of a program is decided. This usually occurs at a very early conceptual design stage in the program. However, the same research has illustrated that there appears to be much greater cost variance, and, therefore, active cost control, in the operations and support phase.

By seeking business models that tie together all stages of program life cycles, it is the objective of this research to enable true cost sharing to occur in defense acquisition, lowering the liability of government to cost overruns while ensuring contractors are incentivized and enabled to participate in cost sharing. They would then be able to spread their own risks over a full program life cycle, in a way familiar to commercial organizations engaged in the production and support of complex systems (Davies & Hobday, 2005).

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Section I. Overview and Background

A. Key Issues in Business Models

The complex technical and commercial risks involved in the development of new combat capabilities have been a recurring source of cost overruns in programs, stretching back many decades. While progress has been made in understanding the root causes of some historical successes and failures in a number of programs, the continued evolution of new technologies, the increasing lifespan of defense capabilities, and the ever-widening gap between new generations of capabilities have made it difficult to apply many of these lessons as widely as would be liked.

Many lessons have been learned and applied to government acquisition processes (Edison & Murphy, 2011; Nowicki, Ramirez-Marquez, Randall, & Murynets, 2011; Wang & San Miguel, 2011). However, these can only have limited benefits without concomitant changes in contractor actions and behaviors in order to ensure that overall program outcomes are those desired. This involves, on the one hand, more realistic cost estimating at the outset of programs, based on realistic estimates of the nature of the technical risk involved in a program. However, estimates are not a method of controlling unexpected increases in risk and cost, only of reducing the extent of the variance of the possible outturn in program costs (Pryce, 2011).

In order to enable better control of cost overruns, and to limit the government's liability for these, it has recently been proposed that cost sharing in research, development, test and evaluation (RDT&E), and possibly also production, be pursued as a possible palliative (DiMascio, 2011). Cost sharing would see the government limit its liability to program costs at a percentage less than 100%, with figures of around 25% being quoted publicly for the associated liability of contractors. In such a cost-sharing scenario, contractors are theoretically incentivized to minimize cost overruns by their liability for a share of the total program costs.

While this can bring a welcome element of commercial practice to the development of new technologies, it is by no means an assured way of reducing risk. Indeed, it may simply serve to reduce the level of technical risk by reducing the advance in the level of warfighting capability being developed to one that is little more advanced than the current state of the art. In such a case, while costs may be less likely to overrun, and may be lower overall than a more advanced capability, the benefits of the lower risk solution may be sufficiently low to make it a poor choice in terms of cost/effectiveness when compared to an apparently more risky, but higher capability, system.

The judgment of program costs, risks, and capabilities is a constant challenge in all high technology areas. However, it is not just defense that suffers from these difficulties. In major civil aerospace programs similar issues also pertain. The recent lessons of how cost overruns in RDT&E can surprise even the most careful commercial organizations are shown by the case of the Boeing 787 and Airbus A380 airliners, where unexpected technical risks caused huge cost overruns in the order of billions of dollars (Norris & Wagner, 2009). However, the ability of commercial organizations to spread the impact of these risks over a full production, operations and support cycle, as well as utilizing financing mechanisms in the commercial market, means that they are able to absorb such risks, and attendant cost overruns, in the development stages.

It is the purpose of the research reported here to outline how defense acquisition could use cost sharing across the life cycle to enable capability sustainment in a way that benefits government and contractors, using commercial practices and experience, while allowing technical advances to be made that warrant the costs incurred. In this report, these aspects are illustrated by a number of case studies, with more detailed reporting on two of the case studies, the Harrier and Typhoon combat aircraft from the UK, used to illustrate the full range of issues.

B. Research Approach

In order to allow cost-sharing benefits to work for both government and contractors, it is essential that the business models used for each program be tailored to meet the needs of both parties. In the United Kingdom the Ministry of Defence and several major contractors (such as BAE Systems and Rolls Royce) have spent many years moving towards the contractor provision of support for availability (Booth, 2011). This has been a difficult process, and one of the many lessons learned has been that a “one-size-fits-all” approach does not work. However, a number of successful availability support contracts have been created, and valuable experience gained from them.

In the UK, the Harrier and Typhoon programs have been the source of business model innovation, as well as indicating some of the limits of them. In particular, it has been found that within each program a process of constant evolution is required, as new operational practices, technological advances, industrial re-organizations, and government policies have had a significant impact on the capability support enterprise. A number of other significant issues have been found to recur in the UK, and, over time, it has been seen that the business models need to be built in such a way as to accommodate these issues.

Most notable of these is the ability of the customer to terminate the use of a major system, or the development of a program, that can lead to the loss of most of the projected O&S revenue for the contractor over many decades. The most extreme examples of this have been shown in the recent (October 2010) *Strategic Defence and Security Review* (Cabinet Office, 2010). This saw a radical reduction in the size and scope of the United Kingdom’s armed forces, and the cancelation of a number of programs.

This included the removal of the UK’s Harrier STOVL aircraft fleet from Royal Air Force/Royal Navy service, and the downsizing of the RAF’s Tornado strike aircraft fleet, as well as changes to the planned UK acquisition of the STOVL F-35B aircraft in favor of the F-35C carrier variant (this decision was subsequently reversed back in favor of the F-35B in early 2012). Both Harrier and Tornado programs had been subject to contractor-led support contracts that had led to significant savings in O&S costs. However, the contracts had been let in such a way as to allow for modifications, cancelations and reductions to the fleets, allowing procurement flexibility.

In contrast, the UK decided to retain its commitment to the Typhoon combat aircraft and the new CVF aircraft carriers in the SDSR. In both cases these were still in the development and production phases, and the contracts for these phases were such that penalty charges for cancelation would have been more expensive than continuing with the programs.

This meant that the desire to retain the development and production of these programs shaped UK defense policy, even though the government is on record as not actually wanting the new aircraft carriers, and of getting rid of the Harrier fleet with regret (Cabinet Office, 2010). In order to save money in the short term, to meet financial limits imposed by the state of the national economy, long-term support contracts have had to be canceled to produce savings, while the shorter term development and production contracts have been retained.

This was brought about by the “traditional” approach to development and production contracts in the UK, with these being subject to tough negotiation, and then “set in stone,” in order to keep the contractor bound to meeting their strict terms. In contrast, as mentioned previously, support contracts have been written in “softer” terms, to account for the changes that happen over time in O&S. On the Typhoon program, the desire to limit life-cycle costs has led to negotiation, with BAE Systems and the other European builders of the aircraft (EADS-Cassidian & Alenia) for a 30% reduction in O&S costs, with a contract signed at the end of March 2012.

However, this approach is less than ideal. In order for government to meet short-term savings, it finds itself committed to the annually more expensive, rigidly contracted, development and production of systems it does not want, while contractors may lose the larger total value of long-term support contracts in order to retain the short-term, and more risky, development and production contracts.

In order to try to evolve a more sensible approach, where decisions can be made on a life-cycle basis, this report illustrates the issues that inform the development of business models where risks and rewards can be spread over entire life cycles, allowing decisions on programs to be made on the basis of their overall, long-term benefits and costs.

The overarching research issue that lies behind this report is this: What business models will allow government and industry to benefit the most from cost sharing across program life cycles? The intended research result is, then, to identify business models that can address this issue, depending on the type of program, timescales, and other factors.

The research questions are the following:

1. What benefits can be obtained for government and industry from cost sharing across program life cycles?
2. What are the best business models to enable these benefits to be realized?

The research will answer these questions by looking at a number of case studies from the perspective of programs, technologies, and operational approaches, and by considering how UK experiences can be transitioned to the U.S. defense acquisition environment.

As an initial step of the research, the literature on commercial business models was reviewed in order to identify issues that may be either common to, or different from, defense experiences, needs, and practices.

C. Literature Review

The need to sustain, extend, and modify defense equipment and organizational capabilities over a period of decades means that defense acquisition faces challenges that feature little in the existing academic literature on business models. There have been a number of definitions given for what a business model is, but in this report the definition of Casadesus-Masanell and Ricart (2010) is accepted—namely, that a business model is “a reflection of the firm’s realized strategy” (p. 195). This definition is important, as it notes the difference between a business model and a strategy, and the importance of understanding the contingent nature of business models.

Such contingencies derive from the circumstances within which the enterprise finds itself operating. The complex, long-term nature of defense equipment acquisition and use, as well as the need to constantly update technologies and skills in the light of emergent threats, leads to a situation where understanding the need and ability of organizations to respond to multiple, changing interactions (Pryce, 2011) is essential to creating a successful business model.

Even the insertion of relatively simple technologies into existing systems can have profound implications for firms in the civil sector. Bjorkdahl (2009) notes that integrating new digital technology into existing mechanical products and their supporting processes can only work correctly if the firm carrying it out changes its entire business model. Changing the business model, for example by moving to licensing rather than selling technology, rather than the overall strategy (e.g., to dominate a sector), is key to maximizing value for the user as well as the producer. This aspect of user focused-value enhancement also forms part of the understanding of what a business model is that underpins the research in this report.

From the work of Bjorkdahl (2009) and Casadesus-Masanell and Ricart (2010), we can arrive at the working definition of a business model used in this report, namely, that a business model is a method of jointly realizing value for producers and users in an interactive way that goes beyond a strategy and evolves, often rapidly, over time.

This change over time in a commercial field may be a response to external economic and market events upsetting an equilibrium, driving business model innovation in order to lead on to a period of growth (Sosna, Trevinyo-Rodriguez, & Velamuri, 2010). This growth is based on a new equilibrium established by the new business model, which in effect becomes a transition phase between strategies. This differs from the defense realm, where change is constant and any equilibrium is short lived, especially in relation to the multi-decade–long life cycles of much defense equipment.

Rather, in order to engage with defense issues, business models need to adapt in a continuous process in most cases, notably the major platforms and technologies featured in this research. Demil and Lecocq (2010) have identified the need for core parts of an evolving business model to enable a process of “dynamic consistency” in order to ensure that the competitive advantage of the firm still benefits from the process of evolution, as well as the needs of the user. This dynamic consistency is not in the form of a rigid set of relationships between the organizations, resources, or products that the business model is concerned with, but is seen instead in a consistent set of outputs. While for a firm this output is profitability, for the defense community it could be, for example, capability or availability. The business model, as seen by Demil and Lecocq (2010), delivers dynamic consistency by ensuring that profitability and capability evolve in mutually beneficial ways, while being less concerned with fixing a particular set of relationships to do this.

The idea of a business model being concerned with mutual, diverse benefits to users and producers, as well as being subject to constant change over time, is one that sits well with the concept of interactions as being the key lens through which to view the costing of complex products such as defense equipment (Pryce, 2011). While costing operations and support is a difficult proposition, the concept of interactions offers a way of doing this that should also enable the development of business models that recognize the constant state of change brought about by such interactions. It should also illustrate their implications for the cost of O&S, as well as identifying areas of possible mutual benefit (e.g., where capability can be enhanced at little cost in comparison to other possible options).

The case studies in the following section identify approaches by UK industry and the UK armed forces that have already moved in this direction.

Section II. Case Studies

The approach taken by the case studies for the research (Yin, 1994) is to look at each using the concept of complexity and interactions as outlined in prior research (Pryce, 2011), and to relate this complexity to the way that the business models and contracts for development, production, and support have been structured. Two in particular will be looked at in detail, the Harrier and Typhoon, with the other cases used to identify common issues. We will also consider how the contracts might have been written if a long-term approach, across the life cycle, had been taken into account and if the complexity of this approach had been properly understood.

The full set of case studies in the research are as follows:

Programs

• AV-8B/Harrier (U.S./UK)	• Typhoon (UK)
• F/A-18E/F Super Hornet (U.S.)	• F-35 Lightning II (U.S./UK)

Technologies

• Carbon fiber	• Computing

Operational aspects

• Land-based combat aircraft	• Sea-based combat aircraft

The technology cases highlight how business models and contracts may have to change in light of possible changes in materials and computing technologies over time (the implications of such changes are indicated by Hullander and Walling [2008] and Pryce [2011]). The operational aspects cases, notably the impact of sea-based versus land-based operations of combat aircraft on the distribution of life-cycle costs, follows on from research comparing UK and U.S. carrier aviation using the UK "Lines of Development" approach (Pryce, 2009).

A. Case Study 1: UK Harrier

The research reported in this section is largely based on a number of interviews with BAE Systems staff who have been kept anonymous in this research.

During the period 2005–2010 the UK's Joint Force Harrier fleet of STOVL combat aircraft was updated both as part of a planned enhancement of capabilities and in response to their deployment in Afghanistan. In combat a number of new needs were identified and the critical importance of a rapid response by industry was realized. Central to the technical solutions put forward by BAE Systems and partner companies were a number of new capabilities of an advanced nature, implemented using simple tools (Lucas, 2008). This developed into a process known as Rapid Technology Insertion (RTI), which was implemented through the use of a team that was focused around developing and implementing RTI.

Central to this implementation was an approach on the part of industry that managed risk through the anticipation of user needs and partnering with the user to develop and deploy solutions to meet these needs. This approach was carried out within a dynamic contracting environment that saw increasing amounts of maintenance carried out by industry, both in support of RTI and for more routine work.

The RTI process enabled Joint Force Harrier to exploit technologies as they became available and was an important feature in meeting the demands of the front-line squadrons where flexibility, responsiveness, timeliness, and military effectiveness were vital.

Harrier RTI Business Model

In order to meet the emergent needs from Afghanistan, the ongoing updates of the Harrier and additional needs from changes in UK Ministry of Defence (MoD) policy, BAE Systems' Harrier work was carried out as part of a network of stakeholders who formed partnering arrangements. The RTI activities involved the co-ordination of all the other parties in the process of identifying requirements and solutions, gaining contracts, and implementing the preferred solution.

An important aspect of the RTI process was to ensure that requirements that emerged from the Operational Evaluation Unit (OEU) were endorsed by the RTI team before being passed over to the MoD for approval. Unendorsed requirements passed directly to the MoD had been the cause of problems in the past. For example, they led to a narrow Urgent Operational Requirement (UOR) being issued, where the RTI team may have been aware of additional issues around the identified requirement, and its potential solutions, than the OEU's perspective allowed.

This was seen as a vital part of the RTI team's business model, anticipating customers' future needs beyond their stated ones and, therefore, ensuring future business opportunities, as well as speeding up future upgrades as they emerged from customer experiences. This process was enabled by customer representatives working as part of the RTI team and being willing to communicate up the customer hierarchy via the team. The process was greatly facilitated by a key RTI team leader being a former senior Harrier pilot with direct knowledge and experience of front-line operations and of working on an OEU.

The overall structure of the Harrier RTI business model is shown in Figure 1.

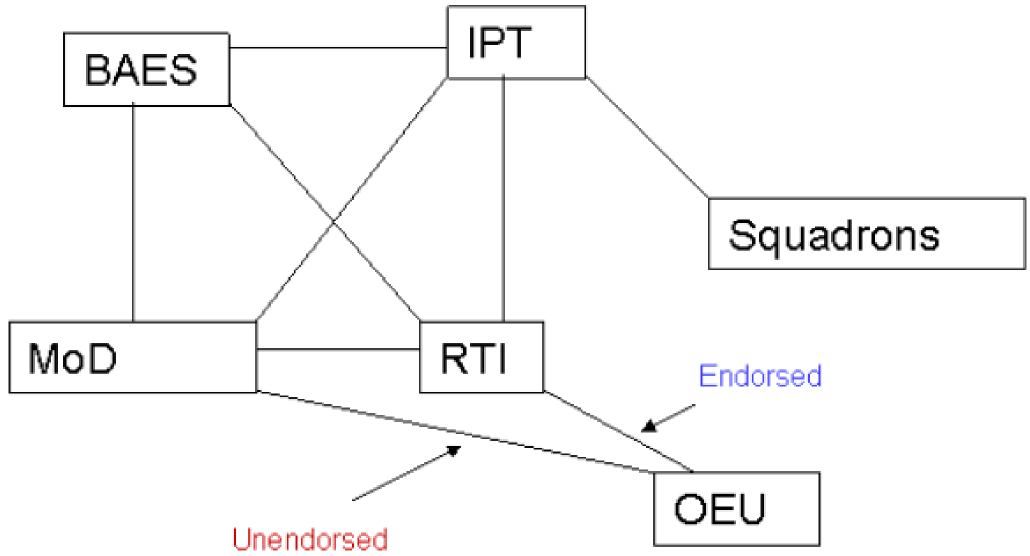

Figure 1. Harrier/RTI Business Model

Notes. BAES = BAE Systems, MoD = UK Ministry of Defence, IPT = Integrated Project Team, RTI = Rapid Technology Insertion team, OEU = Operational Evaluation Unit

Partnering and Private Capital

A central feature of the anticipatory nature of the Harrier RTI team's work was the use of partnering and private capital both to speed up the overall process of technology insertion and to ensure that they were able to link with partner companies ahead of the issue of a specification or a contract from the MoD customer.

An example of this is the integration of the Lockheed Martin Sniper targeting pod (referred to as the Advanced Targeting Pod [ATP]). From September 2006 to April 2007, the RTI program was funded by BAE Systems, with a contract from MoD only following in May 2007. This required BAE Systems and MoD to partner closely with Lockheed Martin, whom they were competing with in other programs, with trust essential to enable this to happen. The ability to focus the business model around the RTI team, rather than at the level of BAE Systems, enabled this flexibility .The overall ATP program of events is shown in Figure 2.

	ADVANCED TARGETING POD - TIMELINE	
2006	First contact with Lockheed Martin	15th September
	Initial Industry Rapid Technology Insertion Meeting	28th September
	Industry funded Aircraft / Pod integration, development and testing	October-November
	First Sniper capability demonstration flight	1st December
	DPA Pod competition	December-January
2007	Sniper selected, Industry resumes integration, development and certification activities	8th February
	Initial OEC Advice Issued for Operational Evaluation (OpEval)	16th March
	Start flight testing of improved software	21st March
	41(R)Sqn OpEval	Mid March – Mid April
	BAE SYSTEMS UOR contract award	11th April
	Integration and certification activities complete and squadron training starts	18th May
	GR9/9A Release To Service	25th May
	GR7A Integration and testing	18th May – 3rd August
	GR7A Release To Service	29th August

Figure 2. Advanced Targeting Pod/RTI Timeline

Note. This chart comes from "BAE Systems Rapid Engineering—Harrier UOR Experiences," BAE Systems personnel communication,2008.

BAE Systems' private venture capital was also used to further develop the ATP solution and to give interim clearance advice to enable the OEU, 41(R) Squadron, to conduct operational evaluation trials in less than four weeks from receipt of a Request for Quotation (RFQ).

Implications of the Business Model

While the Harrier aircraft has many platform-specific issues, such as a relatively low level of systems integration and related cross-systems dependencies (e.g., in comparison to Typhoon), which allowed quick development and implementation of new capabilities, this does not mean that the lessons from Harrier could not be applied more widely. In particular, the partnering approach allowed for by the use of the RTI model appears to be one that could be more readily adopted. Even within BAE Systems this was seen as being of great value and efforts were made to learn internally how the Typhoon aircraft could benefit from the RTI approach pioneered on Harrier.

Externally, the use of a small group, such as the RTI team, that is focused on anticipating customer needs, intimately involved in the development and implementation of requirements, and able to use their own funds to develop work in advance of contract issue, would seem to be of great value in defense acquisition and the sustainment of capabilities over a long time frame.

In order to identify the key factors in the Harrier RTI success, a SWOT analysis was carried out. The results are shown in Table 1.

Table 1. SWOT Analysis of Harrier

Strengths - Small team - UK/BAE controlled - RTI	**Weaknesses** - Small program—little political support - BAE see the "Harrier way" as cheap, so profits low
Opportunities - JSF delay - Combat use - CVF integration trials	**Threats** - Strategic decision to cancel - MoD lose tacit understanding of Harrier IPT methods

Strengths

- Small team. The relatively small team on Harrier (around 600 BAES staff at all locations and in all disciplines), due in part to the fact that it was no longer in production, meant that decisions could be made quickly. All key senior personnel had desks located on one floor of a single building, so decisions could be "walked around" quickly.

- UK/BAE controlled. Unlike a number of other projects, Harrier was effectively a UK-only program. This made decision-making easier as it did not require the agreement of partners in other countries.
- RTI. This is a major factor in the success of the Harrier team and is the basis of their successful business model.

Weaknesses

- Small program—little political support. The fact that Harrier was a relatively small program meant that it was not the main "political" priority for anyone in industry or government. There was a constant need to prove the utility and effectiveness of the program, whereas on other programs (e.g., Typhoon) there was senior managerial and government support. In addition, as the Harrier was not in production, many fewer industrial jobs depended on it.
- BAE's strategic management saw the "Harrier way" as quick and cheap, so lacking in a steady, high-volume cash flow. This lack of "political" support was mirrored in the lower scale of turnover and overall profits (but not profit rate) that Harrier delivered to BAE Systems, which meant that it was not seen as a core program by many managers in the company.

Opportunities

- JSF delay. The intended successor to the Harrier, the F-35B Lightning II Joint Strike Fighter (JSF), is due to enter service at the end of the current decade. Even if it is procured by the UK as planned, the program is still at an early stage of flight testing and manufacturing, and it was thought that the RTI process would need to address these possible delays (before the Harrier's UK cancellation in late 2010).
- Combat use. The experience of Harrier in Afghanistan meant that the squadrons, maintenance organization, and industry had extensive current experience of working closely together to meet customer needs.

- CVF integration trials. The intended replacement aircraft carriers for the Royal Navy, known as CVF, require integration with the aircraft intended to operate from them. The RTI team considered it possible to undertake trials of some common equipment between Harrier and JSF in order to “de-risk” the latter, notably the Advanced Targeting Pod, which is a pod-mounted version of the internal targeting equipment to be fitted to JSF.

Threats

- Strategic decision to cancel Harrier. The UK’s decision to cancel Harrier was realized in late 2010, but had been anticipated as possible by the RTI team, who shaped their activities to reduce its likelihood, although to no avail. However, the Harrier team, much diminished, still supports the international Harrier fleet and the sale of UK Harriers to the United States.
- MoD loses its tacit understanding of Harrier IPT methods. The success of Harrier with its customer was the result of close working with the MoD, who enabled the work to happen in the way it did and supported it in large measure. But as the Harrier RTI team was central to this, their loss may mean the loss of customer knowledge of the business model and how to make it succeed.

In order to see if the lessons of the Harrier RTI business model are more widely applicable, work (interviews and social network analysis) was carried out with contacts at BAE Systems who are working on Typhoon and who are similarly treated anonymously in this report.

B. Case Study 2: Eurofighter Typhoon

The Eurofighter Typhoon combat aircraft program is a large-scale development, production, and support program for the UK MoD and BAE Systems. Features that differentiate it from the Harrier include the following:

- a high level of systems integration and related cross-systems dependencies,

- four-nation international development and production partnership, and
- limited service use and operational experience in limited roles.

In comparison to the relatively agile nature of Harrier RTI activities outlined above, Typhoon can seem rather less adaptable. For example, in interviews with Typhoon engineering personnel in BAE Systems, it was stated that a targeting pod integration similar to the Harrier ATP took seven years on Typhoon, as opposed to the timetable of less than one year for Harrier, shown in Figure 2.

These factors and characteristics mean that a Typhoon business model for sustainment would likely require a different approach to that of Harrier. However, the framework in which it would operate, namely a partnered support and update infrastructure, was in place on Typhoon in its early deployment, specifically the very closely partnered "Case White" introduction to service of Typhoon.

Case White was intended to support the Typhoon's move to its initial UK operational base at RAF Coningsby in July 2005 after a period of "working up" at BAE Systems' Warton facility. It was intended to deliver the ability to deploy the Typhoon overseas and on NATO commitments and, therefore, bridged the initial period in service with the UK Royal Air Force.

BAE Systems were contracted for the provision and support of 1,300 flight hours from Warton, the training of 16 pilots from the Operational Evaluation Unit and Operational Conversion Unit, and the further training of nearly 200 RAF engineering personnel. By operating initially from a BAE Systems facility, and by partnering with the MoD, not just in training engineering personnel, but also in the providing sustainment activities at RAF Coningsby, BAE Systems hoped both to ease the Typhoon into service and to leverage the corporate engineering knowledge gained during development of the Typhoon into the sustainment of the aircraft in service.

Case White itself is considered to have been successful. However, the handover of the Typhoon to the RAF was not as smooth as would be hoped. In part this was due to the Case White engineering and management team at BAE Systems moving to support the purchase of Typhoons by Saudi Arabia. With the full introduction of Typhoon to RAF service there was a subsequent reduction in partnering activities, although the RAF are still aiming to use BAE Systems as part of the overall sustainment activities. Recent contracts, such as the award of the £450 million Typhoon Availability Service (TAS) contract in March 2009 (BAE Systems, 2011), and the signing of a four-nation support agreement in March 2012, appear to be a movement back towards a situation like that in Case White. Notably, the further integration of new capabilities in Typhoon is part of the new support contract, as well as the reduction in support costs, which mirrors the purpose, if not the structures, of the Harrier RTI business model.

The key differences between Typhoon and the Harrier experience are shown in the SWOT analysis summary in Table 2.

Table 2. SWOT Analysis of Typhoon

Strengths	Weaknesses
- Large program - High turnover/long timescale	- Large Team - Four nations—slow - Complex systems
Opportunities	**Threats**
- JSF delay - New weapons/roles	- JSF capabilities - Limited combat use

Strengths

Typhoon is a large program, with significant ongoing production and upgrade activities planned to occur over the next decade.

- Because it is a large program, Typhoon has a high turnover and is, therefore, a core program for BAE Systems, Rolls Royce, and other partner companies, and it also has a high political profile and support due to the large numbers of jobs that depend on the program.

Weaknesses

- BAE Systems staff interviewed felt that the large size of their design and support team was a major problem: With staff dispersed at a number of sites and in various buildings, communication within BAE systems is slowed.
- The communication issue was exacerbated by the four partner nations that form the Eurofighter Typhoon consortium. They add another layer of communication difficulties through issues such as language differences, as well as an even wider set of sites in the four countries and the need to

co-ordinate the technical, political, and financial support of the program, including sustainment activities, across all four nations.

- The technically complex nature of the aircraft and its systems, in part caused by the need for work-share equity between the partner nations, further exacerbated these identified failings.

Opportunities

- The continuing delays in the UK's acquisition of JSF were seen as a major business opportunity for Typhoon, with updates in its air-to-ground capabilities enabling the platform to fulfill some of the intended roles of the JSF.
- This was seen to present opportunities beyond the UK as the new weapons and roles offered by the UK updates widen the Typhoon's market appeal worldwide.

Threats

- While the JSF delays were seen as an opportunity for Typhoon, its significant emerging capabilities mean that Typhoon upgrades may be deferred in favor of JSF, especially as this pushes expenditures to the right into future years, an important consideration in the current UK budgetary environment.
- The first UK combat use of Typhoon in the Libyan campaign of 2011 was seen as a benefit to the program, but the limited range of roles it was engaged in (essentially escort missions) meant that the full range of its capabilities are yet to be combat proven.

This SWOT analysis shows that the Typhoon is in many ways the inverse of Harrier in terms of strengths and weaknesses. This could imply that a very different business model is required in order to support sustainment activities.

The current business model, with BAE Systems partnering with the Royal Air Force to deliver the Typhoon Availability Service contract, has the following main features (BAE Systems, 2011):

- Through the contract, BAE Systems is incentivised to (1) ensure the support outputs to provide enough aircraft on a daily basis to meet the needs of the front line, (2) optimise the whole support supply chain, and (3) provide the optimum value for money support service and deliver the means to reduce the fleet Through-Life support cost.
- TAS involves BAE Systems, the MOD, and RAF personnel working side by side in the following areas:
  - Typhoon aircrew and ground crew training;
  - delivery of depth maintenance and servicing of the aircraft;
  - provision of technical support; and
  - management of spares, repairs, and logistics to maximise availability and minimise costs.
- BAE Systems takes a major role in ensuring the availability of the Typhoon fleet.
- The arrangement will see the RAF's Typhoon aircraft maintained and supported by BAE Systems until the end of 2013.
- The five-year contract will transform the service approach to enable a reduction in fleet Through-Life support cost of £2.5 billion.
- The BAE Systems population at RAF Coningsby will grow to over 300 people.
- The contract is output based, linking support service performance and the profit paid to industry.
- BAE Systems and the RAF are sharing their experience and jointly working on ways to optimise the performance of the service (e.g., flying rates and aircraft availability), whilst developing innovative solutions to reduce the Through-Life cost of support.

- The Typhoon Maintenance Facility, designed specifically to support the Typhoon aircraft, is the most advanced maintenance facility in operation across the Royal Air Force.
- The contract draws on best practices and lessons learnt on previous UK and MOD support contracts.

The final point is an interesting one as it appears from interviews that the identified best practices may be derived in large part from a report by the UK National Audit Office (NAO) looking at the benefits of availability contracting on Harrier and the Tornado strike aircraft. This report reached broad conclusions, backed by specific evidence (National Audit Office, 2007, Contents page):

- Logistics transformation has produced positive results in terms of cost and performance.
- The cost of support has decreased significantly.
- The Department has reduced the manpower required to support depth repair.
- Performance has broadly been maintained throughout the transformation of support to fast jets, with some shortfalls associated with transition.

The NAO's claims have subsequently been challenged by Woodford (2009) as presenting erroneous data and making claims for benefits that exceed the real gains. In particular, Woodford makes the point that industry is not a charity and that it cannot be expected to deliver the same levels of availability or capability at half the cost.

While that might be true in a strict contracting sense, from a business models perspective it makes perfect sense to deliver savings while maintaining capability, as long as the dynamic change implemented by the contractor looks at wider issues, such as those identified in the SWOT analysis mentioned previously for Typhoon. In particular, the ability to enhance the market penetration of the platform by partnering to reduce sustainment costs in the home market can enable further sales and contracts, such as the sale of Typhoons to Saudi Arabia following the Case White experience with the RAF, which saw a significant support element as part of BAE Systems' long-term delivery of systems and services to the Saudi military.

However, Case White also illustrates that if the company does not have the resources to continue supporting all customers to a certain level then it needs to rapidly adapt its business model to ensure it does not prejudice the long-term sustainment relationship with customers. The Typhoon Availability Service has now done this, but it took several years to re-establish the partnering approach established by Case White, and it is clear from interviews that the RAF is cautious about proceeding further down the line of full availability contracting, and possibly even capability contracting, in light of their need to ensure they are not entirely reliant on industry for their operations and support needs.

C. Additional Cases: Programs, Technologies, and Operations

In addition to the cases form the UK looked at in detail, a number of other case studies of programs, technologies and operational aspects were explored in the research.

This section reports them in a briefer manner than the cases of the Harrier and Typhoon, but can relate to those cases in order to establish a matrix of findings.

Program 1—AV-8B Harrier

In the United States, the Harrier aircraft, under the designation AV-8B, is in service with the U.S. Marine Corps. As part of the support of the AV-8B, the U.S. is part of the Harrier Integrated Supply Support (HISS), a five-year, performance-based logistics contract to support AV-8B Harriers operated by the U.S. Marine Corps, Italy, and Spain. The contract can be extended for an additional five years. It supports numerous AV-8B systems and items of equipment, including electrical, mechanical, avionics, and structural components, with approximately 1,000 individual items supported. HISS is worth up to $400 million to Boeing, the principal company involved.

Key differences between HISS and the UK's support arrangements on Harrier reported previously are in two main areas:

- HISS is not intended as a through-life support contract for the components covered or the whole platform.
- As a performance-based contract, the most important aspect of HISS is the delivery time for spares, rather than overall availability or capability.

HISS, therefore, fits with the relatively well-established U.S. approach to performance-based logistics (PBL) that aims to minimize spares holdings and speed up delivery and embodiment of spare parts, as reported by Gansler and Lucyshyn (2006). PBL is essentially a contracting mechanism to deliver benefits similar to commercial lean manufacturing, although applied to the defense support environment, in terms of minimisation of capital employed.

PBL is, therefore, not a business model, but rather a contracting approach to manage financial aspects of O&S activities. While contractors are incentivized to deliver improvements in O&S, they are not specifically encouraged to share costs across the life cycle.

Program 2—F/A-18E/F Super Hornet

The Boeing F/A-18E/F Super Hornet is the primary strike and air defense asset of the U.S. Navy Carrier Air Wings. Developed from the earlier F/A-18C/D family, the Super Hornet has undergone a series of updates, most notably the incorporation of the AN/APG-79 Active Electronically Scanned Array (AESA) radar. The following section is based on material provided by Ted Hermann (personal communication, 15 March 2012) at Boeing St. Louis.

The Super Hornet is 25% bigger than the earlier Hornet. The mission computers and communications gear are the same as the Hornet. Once Boeing solidly identified the AESA requirements, it was determined a new fore body structure made sense for the Super Hornet, different from early deliveries of the aircraft. One of the advantages of AESA radars is that they have exceptionally high mean time between failures, typically longer than the expected life of the aircraft, and can, therefore, be enclosed in the structure, reducing the need for access panels and doors, and so forth, which are a major source of potential leaks, breakages, and other problems that can increase O&S costs.

Boeing and the U.S. Navy took advantage of the opportunity to upgrade the structure for ease of manufacture and assembly, maintenance, strength (all of the AESA and its equipment sits in the nose), and "other" (presumably stealth) considerations. The new structure was significantly stronger and led to a parts count reduction of approximately 40%. Figure 3 summarizes the gains.

	Was	Now	Change (%)
Part count	2,562	1,533	– 40
Fastener count	30,389	14,948	– 51
Cycle days	124	85	– 31
Standard hours	2,483	1,867	– 26
Assembly labor hours	5,900	5,100	– 14 (1st article)
Defect reduction	3,750	600	– 84 (1st article)

Figure 3. Improvements in Assembly Cost Drivers for New Super Hornet Fore Body

(T. Hermann, personal communication, 15 March 2012)

The enhancements brought about by Boeing and the U.S. Navy on the AESA upgrade cost of the order of $300 million to realize, but promise much greater savings in operations and support. This has been done by looking at what can be seen as the total set of interactions between components as well as the support system over the life cycle of the aircraft, as well as the benefits achieved in manufacture and assembly. Although strict cost sharing did not occur, with U.S. Navy funding secured as part of an overall multi-year buy, many of the features of an improved business model that could enable cost sharing were demonstrated on the program.

Program 3—F-35 JSF (U.S. and UK)

The F-35 Lightning II Joint Strike Fighter is currently undergoing operational test and evaluation as part of a U.S.-led international partnership. The UK's first "B" model Short Take-Off and Vertical Landing (STOVL) aircraft was handed over for tests to the UK in 2012.

While the controversies around the JSF program's budgets and timescales focus on research, development, test and evaluation (R,D,T&E) and continue to be discussed widely, it is likely to be in the area of O&S that the greatest costs are incurred.

The business model adopted by the prime contractor, Lockheed Martin, and by the U.S. Air Force, Navy, and Marine Corps has strongly affected the approach in partner nations to O&S. For the UK in particular, issues of weapons integration, such as the new Meteor missile, have proven very difficult to progress in a timely manner and it is unclear if such an update will ultimately prove possible.

The basic assumption of the Lockheed Martin business model appears to have been to "get it right first time," which has proven not to be the case. Considerable costs have been incurred in a weight-reduction redesign, with initial test aircraft needing to be modified after construction and disruption to the early, low-rate production process adding to delays and cost increases. The tightly integrated nature of the aircraft's systems, the need for strict outer mold line control for stealth reasons, and the work sharing between partner nations and companies mean that the the JSF appears less amenable to the kind of modifications to assembly that the Super Hornet benefitted from and that can read across to improved O&S costs.

Technology 1—Carbon Fiber

Carbon fiber has been used in aerospace applications for over 40 years, and is prized for its qualities of lightness, strength, corrosion and fatigue resistance, and the possibility it offers to reduce manufacturing costs through the use of reduced component counts by allowing the manufacture of complex, single-piece structures.

All of the platforms used as case studies in this report use carbon fiber extensively. This use has thrown up numerous problems in operational use that reveal a number of significant issues with carbon fiber. Most significant among these are issues of impact damage causing delaminations in the layers of carbon fiber and the difficulty in repairing or changing carbon fiber structures while maintaining their certified strength and integrity.

These downsides have led to a move away from the more extensive use of carbon fiber, but emerging technologies promise a change in the way that carbon fiber-based O&S is carried out, and offer scope for business model changes to support the material.

A key area identified is that of out of autoclave (OOA) curing. DARPA and Lockheed Martin have recently flown the X-55 Advanced Composite Cargo Aircraft, which has demonstrated the use of large OOA carbon fiber structures. In addition to the major reductions in tooling and other manufacturing costs, OOA offers the prospect of improved repairability of thermoplastic-based composites using techniques pioneered by British Airways in the 1980s (Gardiner, 2011). For military aircraft, subject to much higher levels of damage than civilian aircraft, this possibility of enhanced repairability could mean that composite materials could be added to the list of components that can be supported in performance-based logistics-type contracts, and could reduce the full costs of availability contracting for companies.

Technology 2—Computing

Since 1994, the use of commercial off-the-shelf (COTS) computing technology has been seen as a way to engage with commercial developments to lower the development and support costs of military computing. Although this approach has produced “quick wins,” for example, the OSCAR AV-8B Harrier update, it has also revealed issues such as testing cycles holding up progress and more rapid obsolescence in processor and software cycles, reducing the possible benefits of COTS (Pryce, 2011).

Davies and Hobday (2005) suggest that companies need generic systems integration capabilities in order to deliver solutions such as those offered by COTS. However, the example of the UK Harrier mission computer reported in Pryce (2011), and its contrast with the U.S. OSCAR update, illustrates some of the issues around COTS. While some issues seem “hard wired,” such as the problem of showing that

COTS systems can function in safety critical systems (Lucas, 2008), there were several that were amenable to change and, therefore, were seen as potential business model issues that emerged during interviews with BAE Systems.

The one chosen to be explored here is that in the existing model of systems development there are three levels of software and related hardware:

1. Software integral to hardware, specified and written by the vendor. Prime contractors (e.g., BAE Systems) cannot change this as part of their support activities. Inertial navigation systems are typical of the types of items that come under this category.
2. Software written to a prime contractor specification by a vendor. Flight control computers are typical of this category.
3. Software written by a prime contractor, for example the Operational Flight Program (OFP) that is located in the main mission computers.

In this hierarchy, changes are least frequent at the top and most common at the lower levels, often driven by evolving operational needs.

Using existing development methods means that the support of systems requires separate contracts for items at Level 1, which is essentially what happens in performance-based logistics contracts. However, this is inflexible and constrains the ability of a prime contractor to alter the entire system for maximum benefit at minimum cost. At Level 3, the situation is reversed, with more prime contractor flexibility (e.g., to adapt to new customer requirements).

Essentially, COTS solutions offer the potential to cut costs at Level 3 in operations and support, but less so at higher levels, if traditional business models and contracting mechanisms are used.

Operational Aspects—Sea Based Versus Land Based

In the United Kingdom, defense capabilities are developed and supported using the framework of the Defence Lines of Development (DLODs). These allow for the co-ordination of the development of the different aspects of capability that are needed to create a realisable military capability. The DLODs are collectively referred to using the acronym TEPIDOIL:

- **T**raining
- **E**quipment
- **P**ersonnel
- **I**nformation
- Concepts & **D**octrine
- **O**rganisation
- **I**nfrastructure
- **L**ogistics

It is only by addressing all the lines of development that the acquisition (and sustainment) community can effectively deliver capability to the UK armed forces.

Figure 4 shows an example of how costs for the UK operation of a STOVL strike fighter match with a U.S. ship-based aircraft. The UK STOVL aircraft can operate from land or sea bases and illustrates how the dependence on using the "cat-and-trap" methods of the U.S. Naval carrier air wings affects the distribution of costs.

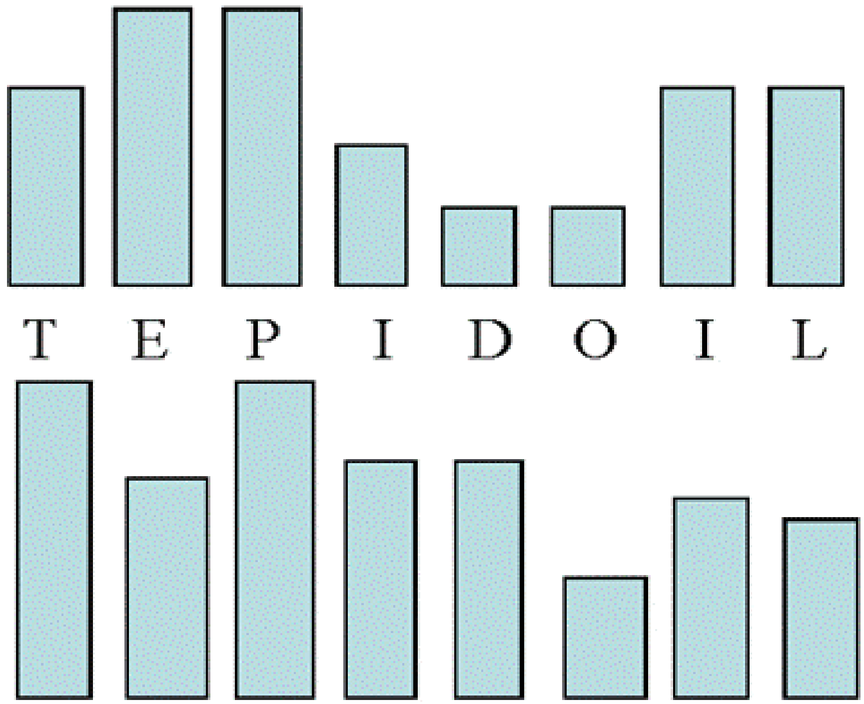

Figure 4. Comparison of UK and U.S. Strike Fighter Costs Spread Across the UK Defence Lines of Development—UK Land/Sea-Based STOVL Fighter (Upper) Versus U.S. Ship-Based Strike Fighter
(from Pryce, 2009)

Most notable is how training costs markedly increase for the more intensive requirements of cat-and-trap operations, while equipment costs are a smaller share of the costs for a STOVL aircraft.

This difference in distribution can have a marked effect. The upper example in Figure 4 is basically the UK Harrier reported in the previous case studies, while the lower example is the U.S. Super Hornet also discussed previously. The difference in cost distributions shows that for contractors to engage in supporting either of these systems successfully, they will need to tailor their support system to fit the cost distribution, or work with the operator to alter the distribution.

Clearly, if the largest single cost is in training then the scope for the largest saving lies here, while if it is in equipment costs then that is the prime area to be addressed. The business model to do either would naturally differ, both to adjust to the reality of the constantly changing nature of operations and support, and to address the constant need for businesses to relocate their central activities to support their customers while developing new business. This highlights the need identified in the literature review to see business models as jointly realizing value for producers and users in an interactive way that goes beyond strategy and evolves, often rapidly, over time.

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Section III. Discussion and Recommendations

A. Case Study Review

The case studies show that the Harrier RTI exercise does appear to have passed muster as being a good business model as it both addressed the needs of the user community for new capabilities, developed and deployed rapidly, and allowed the company to profit from these capabilities. In large part, this success was due to the Harrier RTI team's ability to anticipate future user needs, rather than just responding to them in piecemeal fashion.

The Typhoon case, by comparison, shows that, although the Case White exercise was successful, it was not sustained beyond its initial, narrow objectives and took time to partially recover the close partnering arrangements now in place on the Typhoon Availability Service. Additional sustainment partnering activities have had to start afresh, with a loss of the knowledge previously gained, and the difficulties offered by the complex technical and industrial structure of the program make full partnering for availability a less agile process than on Harrier.

For the other platforms looked at, it appears that although the U.S. experience of performance-based logistics can deliver savings, it is not the way to incentivize contractors to engage across the life cycle. The model used by Boeing and the U.S. Navy on the Super Hornet, with production cost reductions and investment leading to O&S reductions, seems a better basis for innovative business models. The JSF example shows, however, how technical and program issues, as on Typhoon, can limit the scope for the subsequent adoption of Super Hornet-type adaptations.

In the area of technologies and operational aspects, it appears that there are equally subjective benefits and limits to different business models derived from the nature of the technologies themselves and how they are used. In particular, new technologies need to have their potential impact on business models taken into account to realize their full potential benefits.

B. Research Questions Answered

The research questions are here re-stated:

1. What benefits can be obtained for government and industry from cost sharing across program life cycles?
2. What are the best business models to enable these benefits to be realized?

The second research question is answered in Part C, Recommendations for New Business Models. While the first question may appear to suggest the answer that “savings” would be the main benefit that can be offered by cost sharing across program life cycles, this research has indicated that the real benefit may well lie in better understanding by government and industry of each others’ needs, as well as the impact of technical and other forms of change on that understanding.

Cost sharing means that contractors learn to understand all the cost implications of technical changes, while operators better understand the difficulties caused by the disruption that operational changes can throw up. Both are made responsible for understanding the impact of changes through shared costs. The total number of interactions, suggested by Pryce (2011), would be a useful common language for further developing this understanding.

In the U.S., performance-based logistics has readily shown how savings can be realized, but it is in the case of the Super Hornet that the potential of cost sharing can be seen. Although investment came from the government on the Super Hornet, the case of the UK Harrier RTI team shows that true cost sharing is possible, with company investment made in advance of government money.

The U.S. AV-8B and the UK Typhoon experience show that cost sharing may well be a way to advance from, or sustain, existing O&S practices, especially in order to help support new developments in mission computing, weapons integration, etc. These programs are currently limited by their lack of a shared cost basis to stimulate further change and improvement.

C. Recommendations for New Business Models

The concept of the business model has been described here, derived from the academic literature, as being one that is focused on change and outcomes for both users and producers, rather than one of a company adopting a strategy that it then implements in a linear fashion.

A good business model is one that does not define the means, whether organizational structure, resources, or products, but, instead, enables the desired ends of sustainment activities and cost sharing for both contractors and government. The fact that these ends are different for the two sides, and can change over time, is the area where a good business model reveals itself, through its ability to deal with emergent needs and contingent circumstances in an agile manner.

For cost sharing, a business model that allows the identification and establishment of key areas of understanding between government and contractors, and between issues raised in different areas of system life cycles, such as O&S experience being used to shape design and production in order to benefit both, seems to be the main test of success.

The example of the Super Hornet illustrates this potential of cost sharing, if not strictly being an example of it. A business model that would enable this approach more fully is, however, clear in the case of the UK Harrier RTI work, which can be seen as an exemplar of how things can be done in a well implemented, adaptable, and smart business model.

It is unfortunate that the recent purchase by the U.S. of the UK's Harrier fleet has focused solely on the purchase of the aircraft themselves and their breaking out for spares in support of the existing U.S. AV-8B fleet. A far greater benefit could be realized by the adoption of the UK's RTI Harrier business model by the U.S., which I would suggest is the best existing model we have to build on in the future.

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- Cold-Chain Logistics
- Contractors Supporting Military Operations
- Diffusion/Variability on Vendor Performance Evaluation
- Evolutionary Acquisition

- Lean Six Sigma to Reduce Costs and Improve Readiness
- Naval Aviation Maintenance and Process Improvement (2)
- Optimizing CIWS Lifecycle Support (LCS)
- Outsourcing the Pearl Harbor MK-48 Intermediate Maintenance Activity
- Pallet Management System
- PBL (4)
- Privatization-NOSL/NAWCI
- RFID (6)
- Risk Analysis for Performance-Based Logistics
- R-TOC AEGIS Microwave Power Tubes
- Sense-and-Respond Logistics Network
- Strategic Sourcing

Program Management

- Building Collaborative Capacity
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Collaborative IT Tools Leveraging Competence
- Contractor vs. Organic Support
- Knowledge, Responsibilities, and Decision Rights in MDAPs
- KVA Applied to AEGIS and SSDS
- Managing the Service Supply Chain
- Measuring Uncertainty in Earned Value
- Organizational Modeling and Simulation
- Public–Private Partnership
- Terminating Your Own Program
- Utilizing Collaborative and Three-Dimensional Imaging Technology

A complete listing of research topics as well as electronic copies of published research are available on the ARP website (www.acquisitionresearch.net).

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